NExBTL® Renewable Diesel
Singapore Plant

NORTH AMERICAN TECHNICAL CORN OIL PATHWAYS DESCRIPTION

1 INTRODUCTION

Neste Oil is the world's leading producer of Renewable Diesel with on-line capacity of 2 million metric tonnes per year (2 Mt/a) equivalent to 675 million gallons per annum distributed among its three world-wide facilities in Porvoo, Finland; Rotterdam, Holland and Singapore. Branded under the name of NExBTL®, this Renewable Diesel is a fungible, low-carbon, low-emission, paraffinic biofuel. Compared to fossil diesel, NExBTL® has a higher cetane number, contains no aromatic compounds or sulphur. This translates into superior combustion properties to petroleum diesel.

This pathway report summarizes details for the NExBTL® distinct pathway for technical corn oil under the Low Carbon Fuel Standard (LCFS). The CA-GREET model (version 1.8b, December 2009) was used to assess the life-cycle emissions of greenhouse gases for this pathway which represents the operating scenario for the NExBTL® renewable diesel plant in Singapore. This report supports the current pathway.

Corn Oil rendering and supply to the Neste Oil NExBTL® Renewable Diesel (RD) Singapore plant process is described. Corn Oil is imported from North America. Shipments vary by source and an average distance is calculated. Rendering energy corresponds to the California low energy rendering process.

1.1 NeXBTL® Renewable Diesel Site Location and Capacity

This report outlines the NExBTL® Renewable Diesel production process as realized in the Neste Oil Singapore facility located at 1 Tuas South Lane, 637301 Singapore using corn oil feedstock. The refinery is built in the Tuas Industrial District, around 30 minutes from the center of Singapore. The refinery is integrated into the area's existing industrial infrastructure, and makes use of local site utilities and port and storage services. The facility has a design renewable diesel capacity of 832,000 metric tonnes per year.

1.2 Summary of Proposed Pathways

Neste Oil is applying for two new distinct renewable diesel pathways using corn oil as a feedstock. The first pathway applies to corn oil that is sourced from dry mill ethanol plants that produce dry distiller's grains, and the second applies when wet distiller's grains are being produced. The calculated carbon intensity of RD produced from dry DGS derived corn oil is lower than from wet because the life cycle analysis model applies a natural gas dryer energy savings avoidance credit (equal to 30.66 gCO_2e/MJ) to this pathway.

The carbon intensity for the two proposed pathways has been calculated using the CA-GREET model which has been modified by ARB to compute the carbon intensity for biodiesel from corn oil. A number of modifications have been made to the model to reflect the specific processes and transport routes of

the proposed NExBTL corn oil renewable diesel pathways. The carbon intensity is summarized in Table 4.

Table 1: Diesel Pathway Descriptions and Carbon Intensities

Proposed NExBTL Pathway	Scenario	CI Estimated using CA-GREET (RD transported by rail)
MW Corn Oil from Dry DGS to RD	Corn oil extracted from DGS at plants producing 100% Dry DGS collected in MW, shipped 50 miles by truck, 1700 miles by rail to port of LA by rail, and 7,677 nautical miles by ocean tanker to RD facility in Singapore using NExBTL process. RD transported 7,677 nautical miles by ocean tanker to California.	16.73
MW Corn Oil from Wet DGS to RD	Corn oil extracted from DGS at plants producing 100% Wet DGS collected in MW, shipped 50 miles by truck, 1700 miles by rail to port of LA by rail, and 7,677 nautical miles by ocean tanker to RD facility in Singapore using NExBTL process. RD transported 7,677 nautical miles by ocean tanker to California.	39.13

2. PATHWAY DESCRIPTION

The process of producing renewable diesel at Neste Oil's NExBTL plant in Singapore using North American Technical Corn Oil is herein described.

2.1 FEEDSTOCK UTILIZATION

Corn oil is collected from dry mill corn ethanol plants located in the Mid-Western United States and supplied to the Neste Oil NExBTL® Renewable Diesel (RD) Singapore plant. Suppliers of corn oil vary regularly and specific details of the supply logistics are different. A conservative case was assumed where shipment distances represent a maximum likely case. Corn oil sourced by Neste meets the US EPA's definition of "non-food grade corn oil" and eligibility requirements established in 40 C.F.R § 80.1426 as corn oil that originates from back end separation from distillers grains at dry mill corn ethanol plants.

This report describes the corn oil feed procurement and shipping to the NExBTL® Renewable Diesel production plant located in Singapore in Tuas Industrial District. This data was used to modify the CA-GREET model for the calculation of GHG emissions.

2.2 CORN OIL EXTRACTION PROCESS

***** CBI ***** Therefore, Neste assumes that corn oil extraction from DG at corn ethanol plants occurs in the same way as modelled by ARB in its CA-GREET model for Biodiesel from Corn Oil. Specific, assumptions include:

- A default corn oil yield of 0.065 gallons per gallon of ethanol at dry mills;
- A natural gas savings of 3,700 Btu/gal applies at the DGS dryer; and
- Default assumptions for energy use and allocations in corn oil extraction at ethanol plants.

2.3 FEEDSTOCK PROCUREMENT

***** CBI ***** Corn oil is put on rail cars and transported to ports of export for shipment by oceanic tanker to Singapore. The model assumes that corn oil is collected and shipment by truck 50 miles to rail yards then shipped a distance of 1,700 miles by rail to the port in Los Angeles. The feedstock is then shipped 7,677 nautical miles to the Neste Oil NExBTL® Singapore plant for processing. The transport distances vary among starting origins and shipping ports, but have been calculated in the model using a conservative route which maximizes the rail transport distance and minimizes the ocean tanker transport distances.

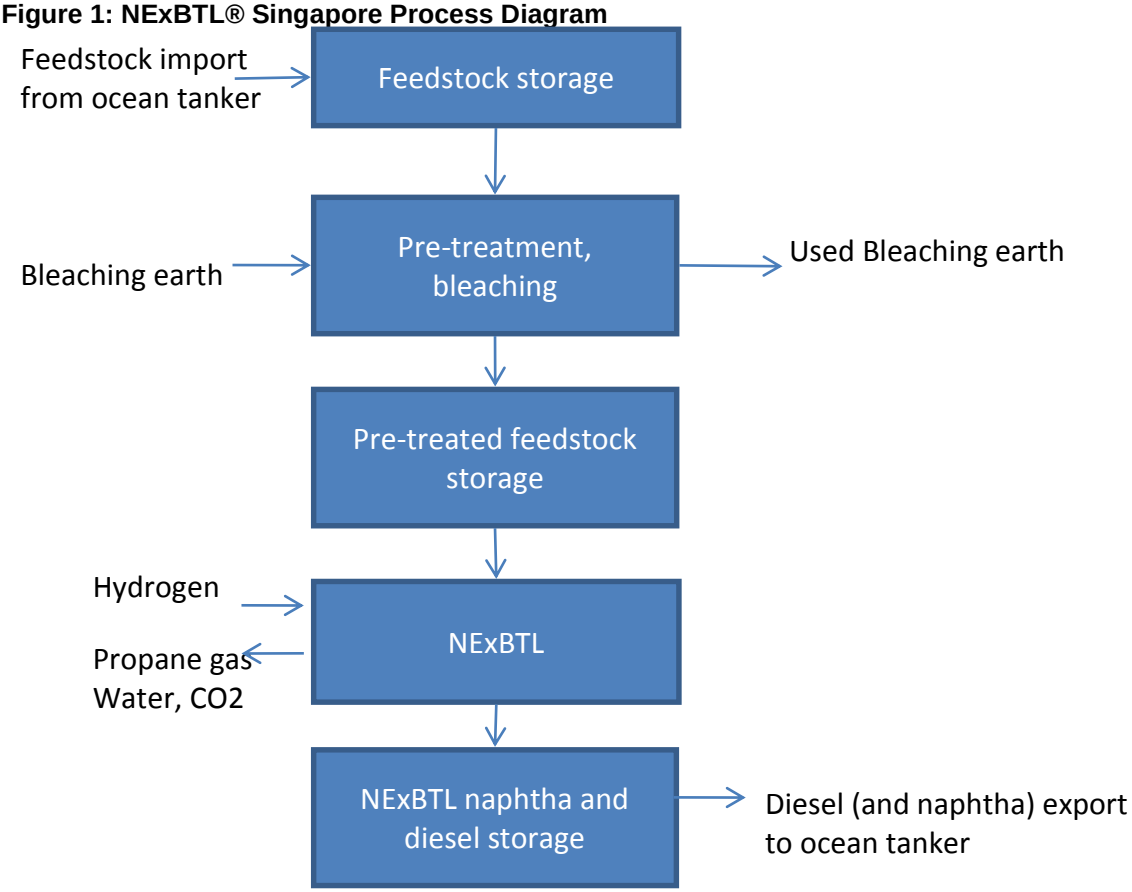
2.4 NExBTL® PROCESS OVERVIEW

The overall features of the Singapore NExBTL® Renewable Diesel production plant are shown in Figure 1. The process is comprised of a number of sub-process units which are described in greater detail and include:

- Pre-treatment (impurities removal);
- Hydro treatment (oxygen removal, paraffins production and branching; propane production)
- Stabilization (removal of residual light gases); and
- Recycle (hydrogen recovered & recycled; water, carbon dioxide removal, light gases recovered).

The propane off gas from the Recycle section is used in the steam methane reformer (SMR) plant for the production of hydrogen and the propane off gas from the Stabilization section is used in a natural gas boiler to raise process steam.

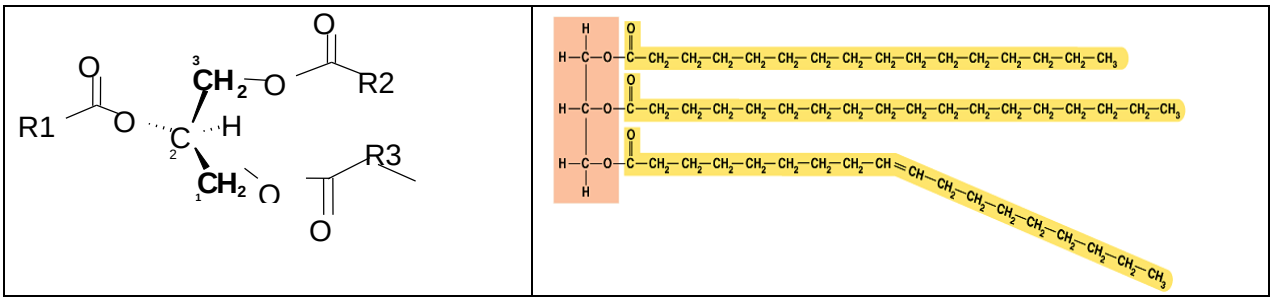
Figure 1: NExBTL® Singapore Process Diagram



2.5 THEORETICAL MASS BALANCE

The feedstocks for the process include numerous vegetable oils and animal fats including fish oil, tallow, used cooking oil, palm oil and corn oil. NExBTL® Renewable Diesel plants are also able to process fatty acids . Common triglyceride representations are shown below. The side chains R1, R2, R3 vary by length and are typically in the range of C14 to C18.

Figure 2: Triglyceride Molecule Models



A simplified mass balance for a model triglyceride $C_{57}H_{102}O_6$ (molecular weight 882 g/mole) is presented. Oxygen is removed as both water (H_2O) and as carbon dioxide (CO_2). The ratio depends on the catalyst and particular conditions employed. A typical ratio is shown in the example below. The equation is written without the production of bio-naphtha as only very small volumes of light hydrocarbons are formed.
A simplified mass balance of the renewable diesel process can be written as:

1.18 kg $C_{57}H_{102}O_6$ + 0.035 kg H_2 →1 kg RD +0.05 kg CO_2 +0.1 kg H_2O +0.06 kg C_3H_8

Since there are impurities removed in the pre-treatment of purification stage which must be removed prior to processing, a slightly higher amount of feed is needed than in the above equation.

2.6 DESIGN CAPACITY

The Singapore plant has a design capacity of approximately 114 tonnes / hour of feedstock. Based on an annual operating hours of 8760 hours this translates into 832,000 tonnes / year of NEXBTL renewable diesel. ***** CBI *****

2.7 ACTUAL SINGAPORE MASS BALANCE

The Singapore plant was officially opened in March 2011. During the start-up period, the plant capacity was raised and individual process units thoroughly tested. The results of energy and mass balances during the start-up phase of a production plant are not relevant for use in GHG calculations as the plant is not operating in a steady-state mode and the energy consumption and chemicals consumption are not representative of full capacity values.

The mass balance ***** CBI ***** is shown in Table 2. By comparison of the realized mass balance to that calculated from reaction stoichiometry in Section 2.5, it can be seen that the actual values are very similar to the calculated values. Combining the values of HP & LP off gases (containing bio propane) produces a yield of 0.06 tonne of recovered energy per tonne of NExBTL. The carbon dioxide and water amounts are not reported in the table.

Table 2: Mass Balance NExBTL® Singapore

	t per t NExBTL®
Pretreatment Total Feed	1.21
NExBTL® Unit Feed	1.18
Hydrogen to NExBTL® Unit	0.038
NExBTL® Unit Production and Yields	
NExBTL® Product	1
Bio naphtha Product	0.0052
HP propane rich off gas	0.0505
LP propane rich off gas	0.0096

2.8 FEEDSTOCK PRE-TREATMENT

The function of the pre-treatment unit (PTU) is to reduce the level of impurities in the feed to acceptable levels and thus ensure a long catalyst lifetime.

The pre-treatment unit is designed for the continuously processing of vegetable oils and fats. The pre-treatment process is based on a bleaching unit (BLU). The bleaching unit can be operated independently from the rest of the plant and the operational configuration depends on the type and quality of the feedstock to be treated.

The bleaching process begins with the addition of an acid, forming a salt and removal of the salt by precipitation. The resultant feedstock is then fed through silica and/or bleaching earth which act as adsorbents for further reduction of impurities. Spent bleaching earth is disposed off-site.

The levels of acids or bleaching earth used are in the range of 0.003 to 0.0003 kg /kg of NExBTL® Renewable Diesel.

2.9 HYDRO TREATING

Hydro deoxygenation (HDO)

The catalytic hydro treatment of triglycerides occurs through consecutive reactions forming three, straight chain paraffins; plus propane, water and carbon dioxide with the amounts described earlier. There is 100% conversion of triglycerides in the reactor. This reaction step is normally referred to as hydro deoxygenation or HDO. The reaction takes place by contacting the triglycerides with hydrogen over catalysts at elevated temperatures and pressures. The HDO hydro treating reactions are exothermic. The excess heat that is produced must be removed from the process. This excess heat is used to heat up the incoming feed. This reduces the requirement for external energy. The gases

produced during this step are fed to the Recycle section after water has been condensed out for recycle and reuse.

Isomerization

After the HDO step, the paraffins are branched or isomerized. Isomerization is used to improve the cold flow properties of the final fuel. The reaction is carried out in an atmosphere of hydrogen but there is negligible hydrogen consumption in this step. Next the liquid hydrocarbons are fed to the diesel stabilization column.

2.10 HYDROGEN PRODUCTION

Hydrogen is produced off-site in a Steam Methane Reformer (SMR). The SMR Plant is located on nearby Jurong Island and connected to the Neste Oil Singapore plant via a hydrogen pipeline network. Hydrogen consumption was approximately 0.1 MJ / $MJ_{NExBTL®}$. (0.038 t/t NExBTL).

Both natural gas and propane rich HP off-gas is used in the SMR plant. ***** CBI ***** HP propane rich off gas was sent off site to the SMR for hydrogen production via a dedicated pipeline. The natural gas used in the SMR is from the local natural gas network that is imported from Malaysia and Indonesia.

2.11 STABILIZATION

Product from the isomerization reactor is routed to the stabilization column where light hydrocarbons are separated by stripping with low pressure steam. The stripping steam is generated in the waste heat boiler from condensate with heat of the diesel stabilization column bottom product. Hydrocarbons that are stripped are called LP off gas.

2.12 GAS SEPARATION AND RECYCLE

The function of this section is to separate the gas mixture into individual gas streams for use or removal and disposal. Hydrogen is returned to the process for use while the high pressure (HP) propane rich off gas is sent to a steam methane reformer (SMR) for hydrogen production and low pressure (LP) propane rich off gas is sent to a natural gas steam boiler for process steam production and to a fired heater for process heating.

The gases are selectively and sequentially removed by first absorption or washing with an aqueous amine solution followed by amine regeneration where the individual gases are separated. The recycle section is comprised of a number of wash columns and regeneration columns. The carbon dioxide and water streams are cleaned before releasing to the atmosphere or to the wastewater system.

Hydrogen is recovered by its selective permeation through a membrane. Hydrogen is then compressed and ready for use in the process.

2.13 CO-PRODUCT HP PROPANE OFF GAS CREDIT

In the recycle section of the Neste Oil Oyj Singapore plant, , the biogenic propane rich HP off gas generated by the process displaces an energy equivalent of natural gas (NG) that would otherwise have been consumed as both process fuel and as feedstock in the SMR. A greenhouse gas savings is

realized at the SMR unit due to the use of HP propane rich off gas from the RD plant displacing natural gas that would otherwise be used.

Based on the production figures for the Singapore plant during the time period in question, the propane rich HP off gas value had a GHG credit value of 3256.85 g CO2e/MMBtu NExBTL or 3.09 g CO2e/MJ NExBTL.

2.14 STEAM CONSUMPTION AND STEAM & HEAT PRODUCTION

The Neste Oil Singapore plant is located in the Tuas industrial area which is adjacent to the Tuas power plant. The process steam used in the Neste Oil NExBTL Singapore plant is produced in a natural gas boiler in the Tuas Power Plant. The boiler utilizes natural gas from the natural gas network and the low pressure (LP) propane rich off gas from the NExBTL Singapore plant. Part of the heat needed in NExBTL process in generated in fired heater using natural gas from the natural gas network and some the low pressure (LP) propane rich off gas. The NExBTL process thermal energy inputs were calculated by ARB staff using plant energy purchase invoices and product sales receipts. As the propane rich off gas is of biogenic origin, only the use of natural gas contributes to net greenhouse gas emissions.

2.15 POWER CONSUMPTION

During the period from September 1, 2011 to June 31, 2013, electrical power consumption in the Neste Oil Singapore NExBTL® plant was 163.58 BTU/lb $_{NExBTL}$. This was purchased from the Singapore national electricity grid. The CA-GREET model was modified to include a user defined grid mix to approximate life cycle emissions from electricity use in Singapore. This grid mix includes 18.4% residual fuel oil fired generation, 78% natural gas fired generation and 3.6% renewables.

2.16 COMBUSTION DEVICES

There are fired process heaters in the NExBTL plant which uses gas from the natural gas network and some the low pressure (LP) propane rich off gas. As the propane rich off gas is of biogenic origin, only the use of natural gas has been considered in the CI calculations.

2.17 NExBTL® PHYSICAL DELIVERY

NExBTL® is transported from the production plant to a storage tank via pipeline over a distance of less than 1 mile. NExBTL® is transported for loading from the storage tank to the vessel via another pipeline over a distance of less than 1 mile.

NExBTL® is then shipped from Singapore to California discharge ports via ocean-going vessels over an average distance of 7,677 nautical miles. Upon arrival, NExBTL® is discharged from the vessel to the onshore storage tanks via pipeline.

3. SUMMARY OF CHANGES TO THE CA-GREET MODEL

*** CBI ***

4. PATHWAY SUMMARY

The final carbon Intensity of the proposed pathway is summarized in Table 3 below using the life cycle stages identified in the ARB corn oil biodiesel CA-GREET model.

Table 3: Carbon Intensity Summary for NExBTL Renewable Diesel from Technical Corn Oil (gCO_2e/MJ RD)

Life Cycle Stage	Corn Oil Extracted at Ethanol Plants selling 100% Dry DGS	Corn Oil Extracted at Ethanol Plants selling 100% Wet DGS
Corn Oil Extraction at Ethanol Plants	13.47	6.01
Corn Oil Transport to Renewable Diesel Plant	7.70	7.70
Renewable Diesel Production	11.14	11.14
Renewable Diesel Transport and Distribution	5.98	5.98
Credit Reduction of DDGS	10.61	10.61
Energy Saving Credit	-29.86	
Propane Rich Off-Gas Credit	-3.09	-3.09
Total WTT	15.95	38.35
iLUC	0	0
Total TTW	0.78	0.78
Total WTW	**16.73**	**39.13**

The carbon intensity for the two proposed pathways has been calculated using the CA-GREET model which has been modified by ARB to compute the carbon intensity for biodiesel from corn oil. A number of modifications have been made to the model to reflect the specific processes and transport routes of the proposed NExBTL corn oil renewable diesel pathways. The carbon intensity is summarized in Table 4.

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5. SUPPORTING DOCUMENTS PROVIDED

To support this Method 2B application, the following documents have been provided to ARB for reference:

***** CBI *****

NESTE OIL

6. DETAILED CA-GREET MODEL CHANGES

*** CBI ***